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SUPPLEMENTAL DEVELOPMENT TESTING OF CRYOGEN COOLED SYSTEMS FOR --ETC(U)

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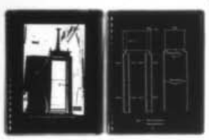

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SUPPLEMENTAL DEVELOPMENT TESTING OF CRYOGEN COOLED SYSTEMS FOR CRYOPUMPING GASEOUS HYDROGEN

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Period Covered April 24 - May 15, 1978

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Gaseous Hydrogen Cryopumping	Hold Time
Controlled Fusion	

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

Three additional type A cryopump assemblies were tested in the Aerospace Research Chamber (12V) test unit, von Karman Gas Dynamics Facility (VKF) during April 24 to May 15, 1978, in support of Neutral Beam Injection work being done by the Energy Research Development Administration (ERDA), Oak Ridge National Laboratory (ORNL). These cryopumps were additional requirements which resulted from previous developmental work at AEDC. The objectives of the tests were to verify operating procedures, hydrogen pumping speeds, and pump operating endurance under operational and steady state conditions. Each pump over

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20. ABSTRACT (Cont'd)

assembly exceeded the operational design requirements specified. Post-test checks and inspections revealed no degradation of pump components due to test environments. Upon completion of testing, the pump assemblies were shipped to ORNL for incorporation into their Neutral Beam Injection Systems.

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1.0 INTRODUCTION

The work reported herein was conducted by the Arnold Engineering Development Center (AEDC) in the Aerospace Chamber (12V), von Kármán Gas Dynamics Facility (VKF), at the request of the Energy Research and Development Administration, Oak Ridge National Laboratory (ERDA/ORNL), Oak Ridge, Tennessee, for Union Carbide Nuclear Division under program element 921G02, Air Force Control No. 9G02-01-8, and ARO Project No. V41R-57.

Seven cryopumps for pumping gaseous hydrogen were fabricated and tested previously under another project. These pumps will be used to remove an excess of ionized hydrogen which is produced in the process of controlled fusion of heavy hydrogen nuclei. There are requirements for additional Type A cryopump assemblies in the continuation of this work. Three were fabricated and tested under this project. They consist basically of liquid helium-cooled surfaces shielded by liquied nitrogen-cooled baffle systems, complete with separate storage dewars for each system.

Additional test support hardware was utilized to simulate the beam chamber and associated equipment.

The data package containing test results was sent to ERDA, Oak Ridge, Tennessee. Requests for data should be addressed to ERDA, Oak Ridge Operations, Oak Ridge, Tennessee 37830. A copy of the data from this test is on file at AEDC.

2.0 APPARATUS

2.1 TEST CHAMBER

The Aerospace Chamber (12V) is a stainless steel vacuum chamber 12 ft in diameter and 35 ft high (Fig. 1). The chamber is lined with a liquid-nitrogen (LN_2)-cooled cryosurface to simulate the temperature environment of space. The cryoliner encloses the sides and bottom of a working volume approximately 10 ft in diameter and 35 ft high. The upper portion of the chamber houses the collimating mirror and integrating lens/window for the off-axis solar simulator.

The chamber vacuum pumping system consists of a 750-cfm roughing pump, a 140-cfm forepump, a 750-cfm Roots Blower, and a 50,000-liter/sec oil diffusion pump. The chamber cryosystem consists of 1272 ft^2 of LN_2-cooled surface and 6 ft^2 of gaseous-helium (GHe)-cooled surface for a scavenger panel.

The chamber pressures and conditions simulated during these tests did not require the use of the solar simulator or cryosystem. A relatively large uncooled test volume and pressures below 10^{-5} torr were provided.

2.2 BEAM CHAMBER

A simulated beam chamber, approximately 3 ft x 6 ft x 6 ft high, was fabricated from thin aluminum sheet and mounted inside the 12V chamber. This was used to approximate the volume and radiation heat transfer background of the actual chamber in which the cryopumps will be used. The aluminum sheet, which represented radiation baffles, was uncooled and was exposed to 300°K 12V chamber walls.

Gaseous hydrogen (GH_2) was bled into the beam chamber, through a diffuser, adjacent to the dump plate.

2.3 CRYOPUMP

2.3.1 Design Criteria

Basic design criteria for the GH_2 cryopump, in addition to specific size and space limitations, are as follows:

Type A Cryopump

1. Condense GH_2 on pumping surfaces cooled by LHe at $4.2^{o}K$
2. Pump GH_2 load $\leq$ 1000 pulses with maximum duration of 500 milliseconds and average gas load of 20 torr/liters/sec.
3. Pump maximum gas load/pulse of 50 tℓ/sec without pump overload or cryodeposit release.
4. Maximum allowable chamber pressure in 10^{-5} torr range.
5. System cooldown to LHe temperatures in less than 16 hours.

2.3.2 Cryopump Physical Description

The cryopumps consist basically of LHe cooled surfaces shielded by LN_2 cooled chevron baffle systems, complete with separate supply dewars for each system. The cryogen dewars are located at the top of the pump assembly, with the cylindrical LHe dewar surrounded by the annular LN_2 dewar. The GH_2 pumping surfaces were located vertically below the dewar and were shielded by LN_2 cooled chevron baffles and radiation shrouds. The A pump utilized two separate panels for the cryopumping surfaces. Operating in a vertical orientation, the pump and baffles are supplied by natural circulation from the dewars. An exploded schematic view of the A pump assembly is shown in Fig. 2. A set of unassembled LN_2 cooled chevron panels for an A pump are shown in Fig. 3. The complete type A cryopump assembly, with adapter flange, can be seen in Fig. 4.

Liquid cryogen capacities and cooled surface areas for the cryopump are given below:

Type	LN_2 Cap. (Liters)		LHe Cap. (Liters)		Pumping Surface (Sq. In.)	
Pump	Dewar	Panels	Dewar	Panels	LN_2	LHe
A	95	11	122	2.5	6292	6600

Installation of a type A cryopump in the simulated beam chamber is shown in the 12V chamber in Figs. 5 and 6.

2.4 INSTRUMENTATION

The 12V chamber pressure was monitored with two Alphatron® gages and two nude hot cathode ionization gages located at various points in the chamber. Pressure inside the simulated beam chamber was measured with three nude hot cathode ionization gages.

Liquid helium (LHe) supply dewar pressure was measured with a ±10 psid transducer. The pressures in both the LN_2 and LHe cryopump dewars were measured by 100 psid transducers. Liquid level of the LN_2 pump dewar was determined and controlled by a Dwyer Photohelic pressure switch/gage with a range of 0-50 in. H_2O column. A Taylor 0-5 in. H_2O range differential pressure transmitter measured the LHe level in the cryopump dewar.

The liquid-nitrogen-cooled chevron panels and dewar were instrumented with chromel-constantan type E thermocouples to determine their temperature. Carbon resistance thermistors were used on the liquid-helium-cooled pump components to cover the temperature range from 90^o-4^oK. Locations of measuring points are shown in Fig. 7.

3.0 TEST DESCRIPTION

3.1 PRETEST CHECKOUT

Each of the cryopump components was leak checked and made vacuum tight before assembly. After assembling the cryopump components the completed pump was again leak checked and its integrity verified. The individual pumps were then installed in the 12V chamber and all cryogen lines and instrumentation hooked up. The complete cryogen systems were again leak tested and system sensitivities measured. All instrumentation was checked out and verified.

3.2 TEST PROCEDURE

A general test procedure was followed while testing each cryopump assembly. The 12V chamber was evacuated to the 10^{-5} torr range. A sensitivity check was then made on each of the cryogenic systems. The cryopump LN_2 dewar and chevron panels were then filled by opening the supply line from the facility system. The LN_2 line pressure ranged from 24 to 26 psi and the vent line returned to the facility gaseous recovery system, with a back pressure of 2 psi. Liquid level in the LN_2 pump dewar was maintained by control of a solenoid valve in the supply line controlled by a Dwyer Photohelic differential pressure sensor. During the initial LN_2 fill the system was permitted to go through one boil-off and refill cycle in order to stabilize the dewar and chevron panels temperature at 77^oK.

To facilitate pre-cooling of the LHe dewar and panels the 12V chamber was back-filled with GHe to 1-5 torr range. The cryopump was maintained at these conditions until the LHe components cooled to near LN_2 temperature, which normally was achieved in about four hours. The 12V chamber was then reevacuated to the 10^{-5} torr range and LHe fill of the pump started.

Several methods were tried during the early LHe fills on the first series of tests to determine the optimal method in terms of LHe usage and time to fill. The following procedure was used as the optimum. LHe was supplied from a 500-liter dewar. The supply pressure was set at 5-6 psi and the dewar LHe dip-stick valve opened approximately one-half turn off of its seat. The LHe discharge line from the cryopump dewar was vented to atmosphere to permit observation of the GHe plume and ascertain that liquid was not being discharged with the exhaust. After initial flow was stabilized the GHe exhaust to atmosphere was closed and the boil-off collected by the facility system. Cryopump temperatures and LHe level in the pump dewar were monitored during fill. When the desired LHe level in the cryopump was reached the LHe flow was shut off and the pump dewar was left vented.

Cooling of the LHe system components from 90°K to the 5-6°K range required 10 to 20 minutes, during which time the entire LHe flow was vaporized. After these temperatures were reached, liquid helium began to fill the panels and dewar. A complete LHe fill required from 40 to 60 minutes after flow was started.

The three cryopumps were tested with gaseous hydrogen inbleed to partially simulate conditions inside a beam line chamber. GH_2 was inbled at various rates from 5 to $\leq$ 70 torr liters/sec in order to determine pumping speeds and the effect of cryodeposits on cryopump operation. The GH_2 was injected into the beam chamber through a diffuser. Each inbleed rate of GH_2 was maintained for two minutes to permit stabilization of the test chamber pressure. The cryodeposit of H_2 on each pump tested was greater than the maximum expected during normal daily operation. Excess H_2 was cryopumped in several instances to determine effects of cryodeposit thickness and breakdown point of the pump.

Determination of steady state boil-off rates, cryopump operating time vs cryogen capacity, and steady state hold time was made with the pump components exposed to constant background radiation heat loads, in addition to the GH_2 heat load. Each of the three cryopump assemblies exceeded the operational design requirements specified. Specific test results are presented in the AEDC Data Package.

Figure 1 Aerospace Research Chamber (12V).

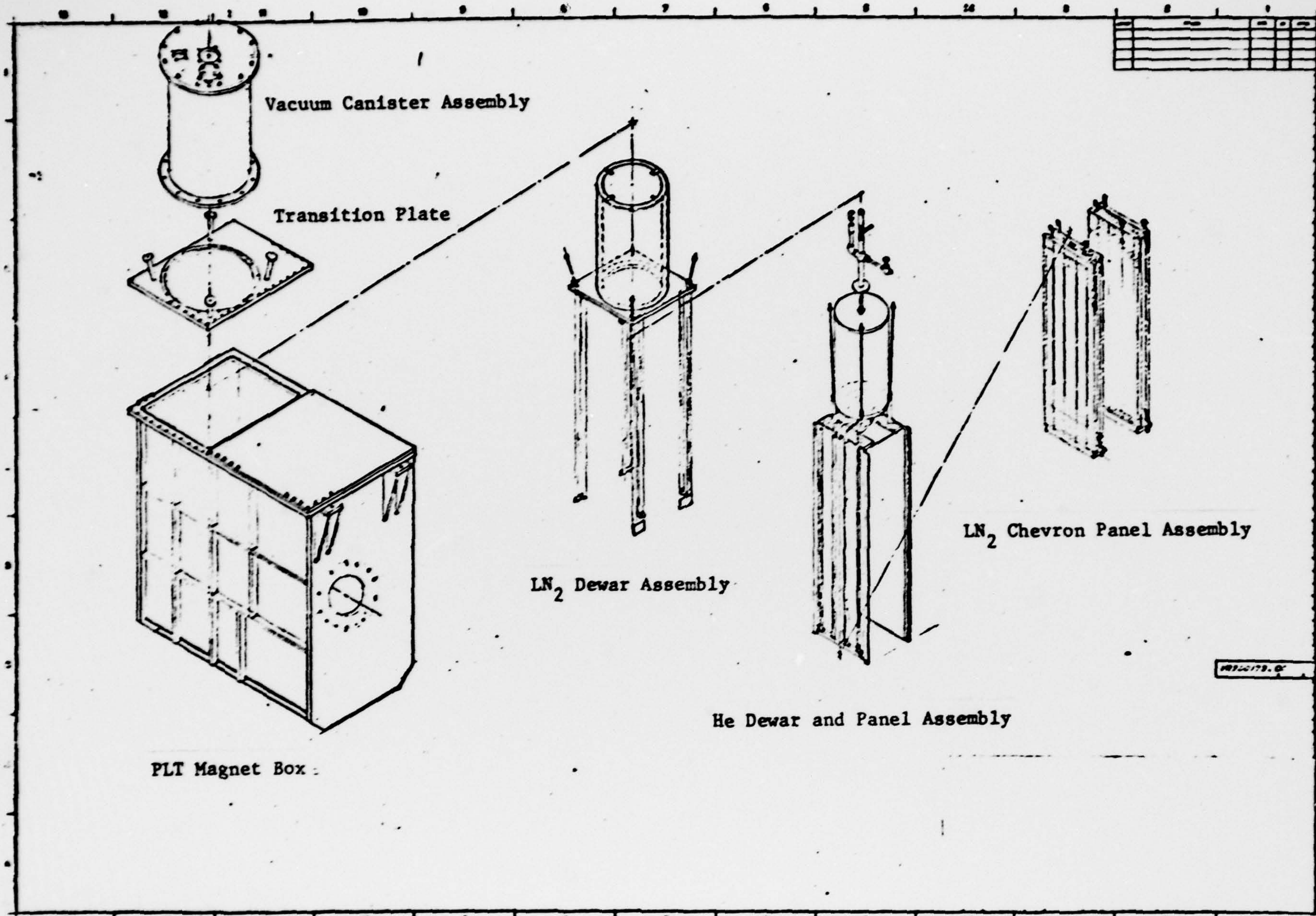

Fig. 2 Type A Cryopump Assembly

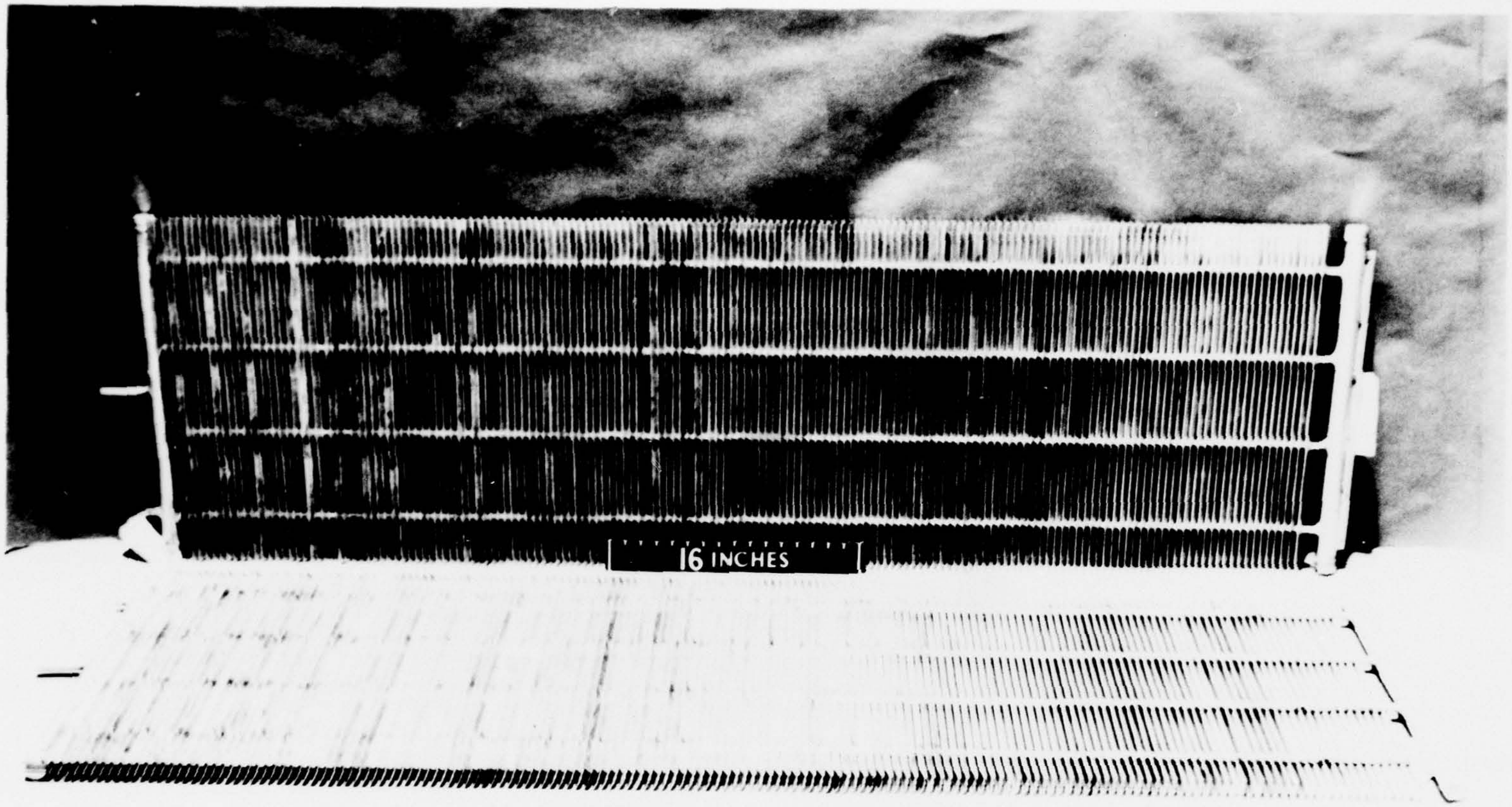

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Fig. 3 Type A LN_2 Cooled Chevron Panels.

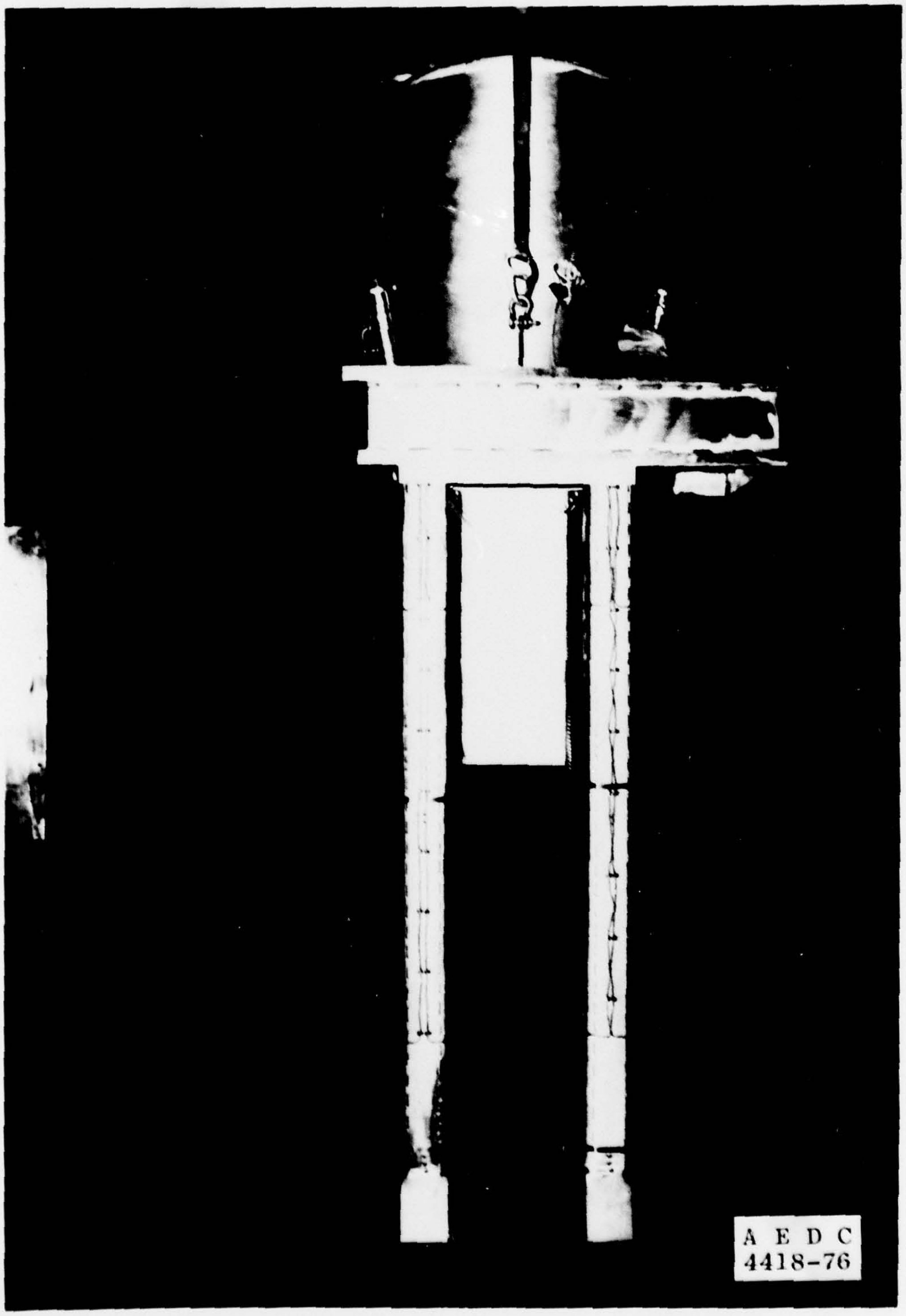
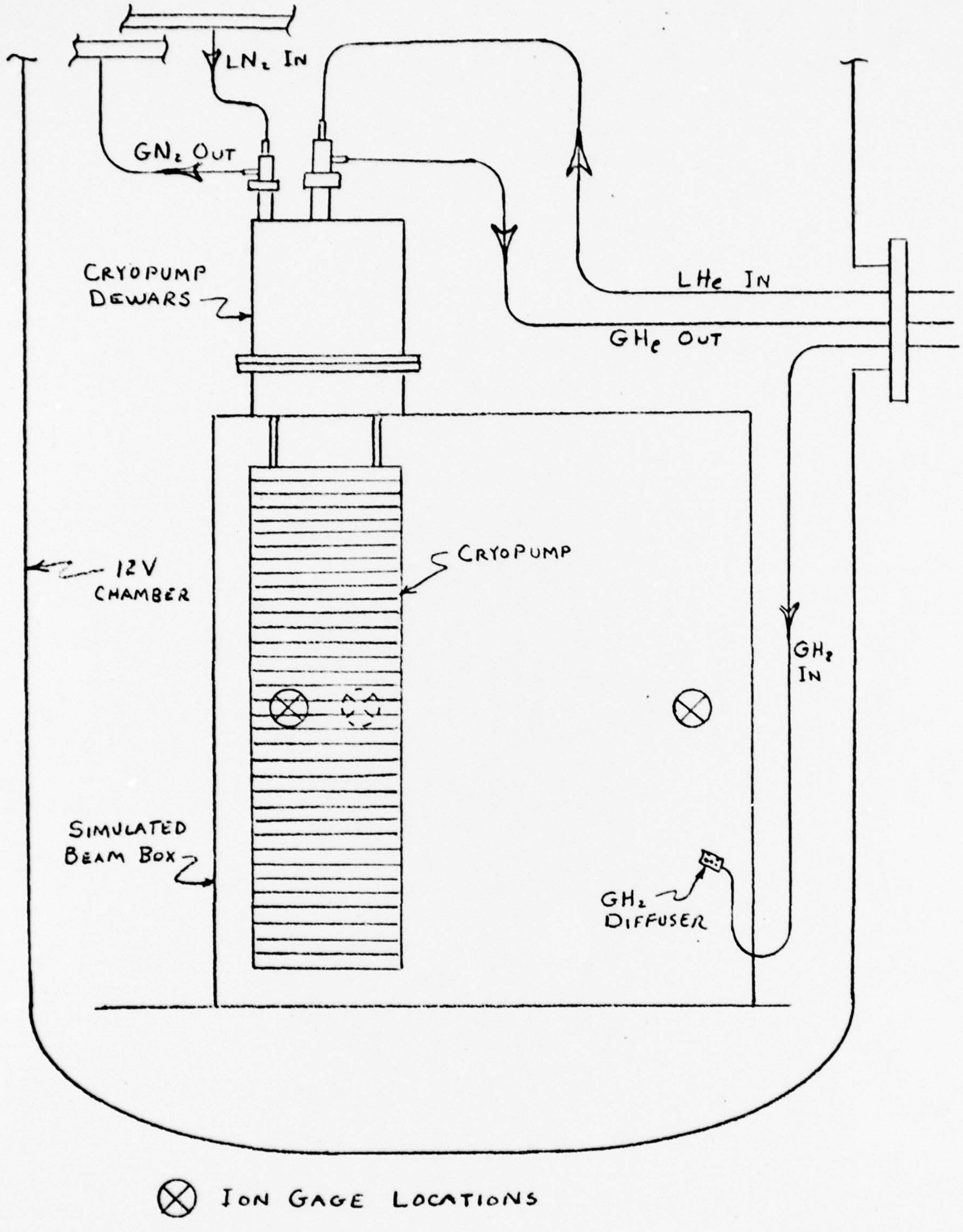
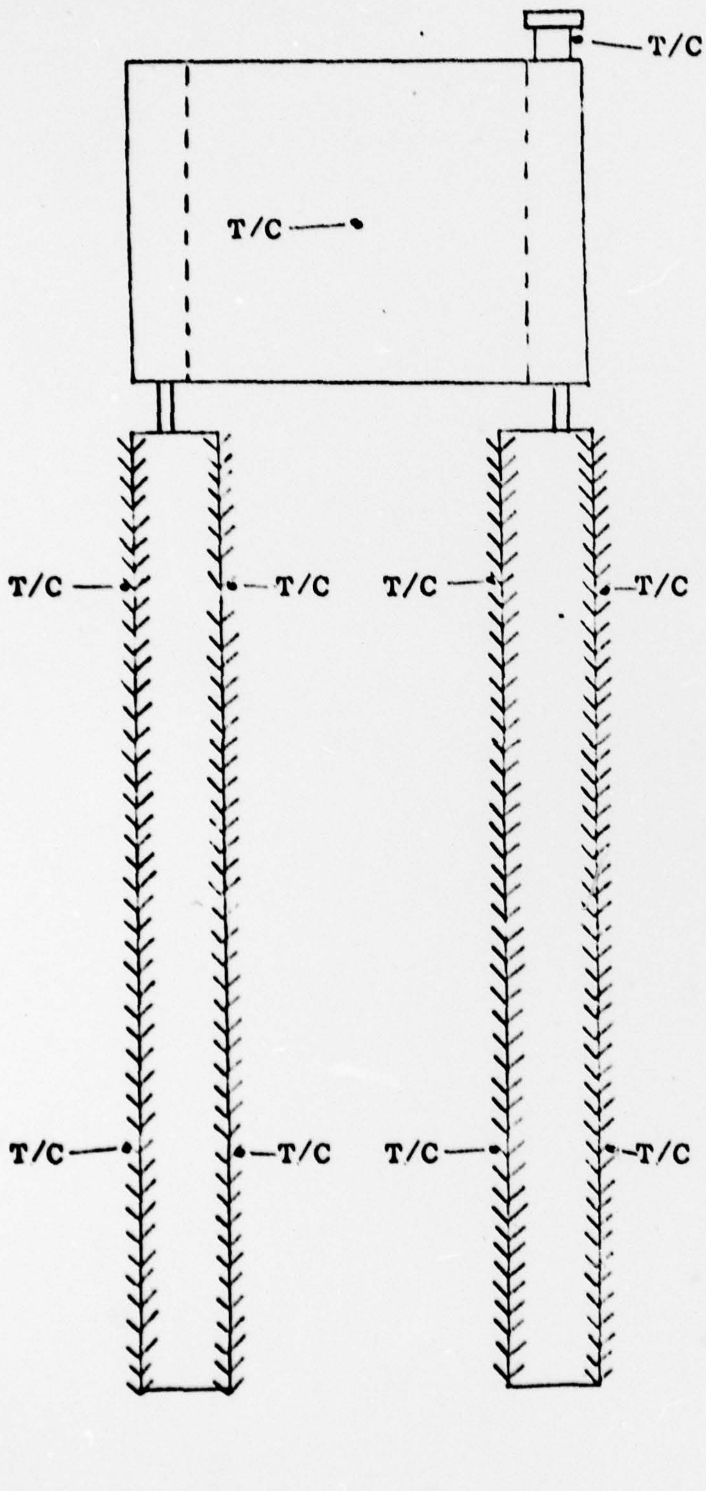


Fig. 4 Type A Cryopump Assembly.



PUMP INSTALLATION SCHEMATIC
FIG. 5

Fig. 6 Type A Cryopump Installation in 12V Chamber.



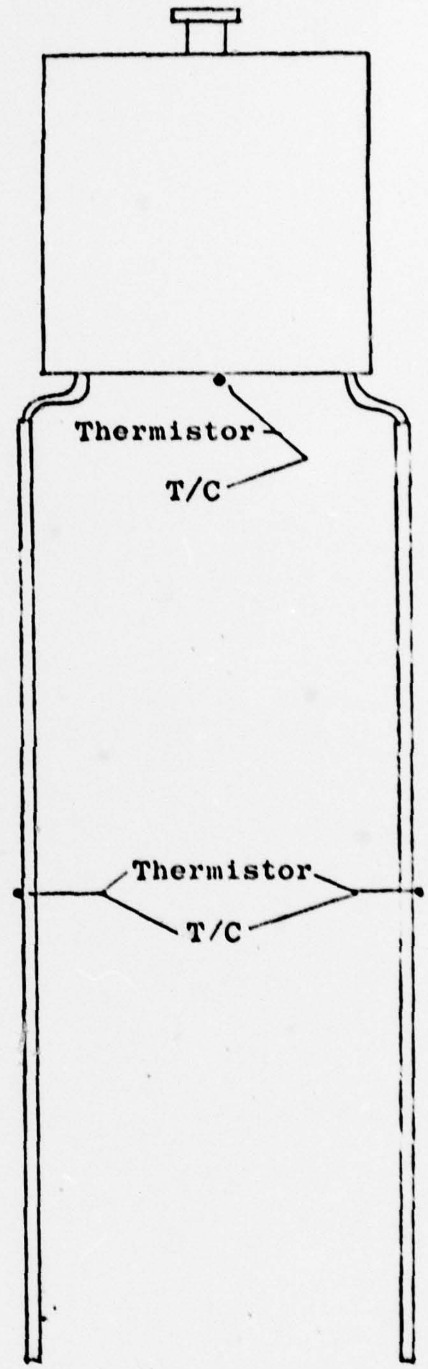


Fig. 7 Type A Cryopump Instrumentation